RESEARCH ARTICLE OPEN ACCESS

Microcontroller Based Current Detection In Ac Locomotives

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ABSTRACT
An electric locomotive is a locomotive powered by electricity from overhead lines, a third rail or an on-board energy storage device.During the course of run of the locos, there arise situations that the motor consumes current that is above the maximum or below the minimum ratings. This phenomenon causes flashover, burning out of contactors etc. If we could prevent these undesirable anomalies a lot of money can be saved and also the maintenance works gets reduced.This necessitates the development of a system that helps us in detecting the unusual current consumption so that all the undesirable anomalies can be avoided. Presently there are no such systems that help us in detecting this problem. This paper aims in developing such a system using a microcontroller that digitally notifies the loco pilot for any unusual current consumption so that if such a situation should arise the specific faulty motor can be isolated before it gets damaged.

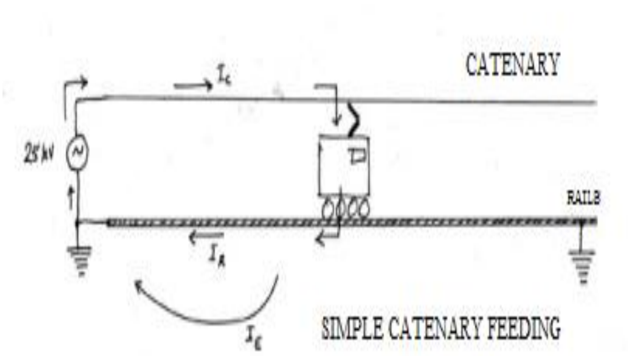
KEY WORDS: Current detection, Locomotive, Microcontroller, Traction motor, Wheel slip

I. INTRODUCTION

The electric Locomotives (WAP4 & WAG7) used by the Indian Railways employs 6 DC series motors. The improvement of adhesion characteristics is important in electric commuter train. Wheel slip is a major problem arising in this. The anti-slip/skid re-adhesion control system based on disturbance observer and sensor-less vector control is already been proposed[1].AntislipReadhesion Control Based on Speed-Sensorless Vector Control was done earlier in Japanese railways[2].But this will not suit our railway system.

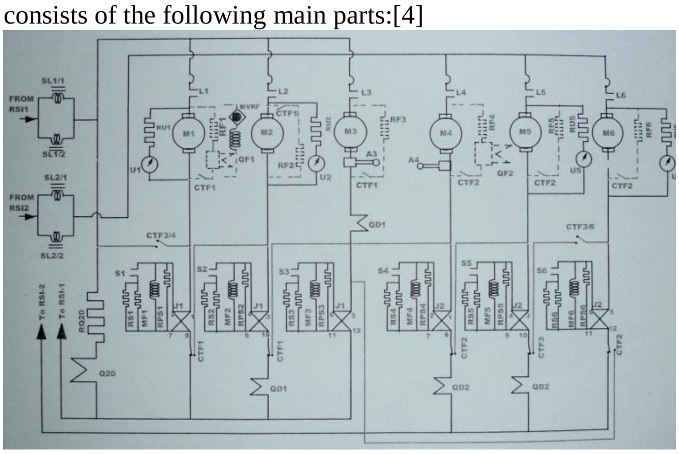
II. OPERATION OF A LOCOMOTIVE

The electric locomotive basically works at 25 KV, 50Hz supply. The 25KV AC supply is drawn from overhead equipment[3]. The supply of electricity is through an overhead system of suspended cables known as the catenary. A contact wire or contact cable actually carries the electricity. The locomotive is equipped with two pneumatically controlled pantographs. The supply from overhead wires is drawn through these pantographs inside to the loco. The pantographs transfer the power to transformer after passing through the normally closed vacuum circuit breaker. Output voltage of the tap changer is fed to the primary of the main transformer. The main transformer steps down the voltage to a lower level. The voltage from the secondary of main transformer is fed to bridge rectifier and then fed to traction motor through the motor contactors and reversors. There are 6 traction motors which works parallel to provide the tractive effort for hauling the train.



III. POWER CIRCUIT OF THE LOCOMOTIVE

The electrical power circuit of the loco consists of the following main parts:[4]



- Main transformer
- Traction motors
- Rectifier
- Smoothing Reactor
- 3 Phase induction motor

IV. TRACTION MOTOR

These are DC series motor which produce maximum torque while starting and suitable for quick acceleration. The speed can be easily varied by varying the input voltage. They are able to move very large shaft loads when it is first energized. The amount of current that passes through the winding determines the amount of torque the motor shaft can produce. Since the series field can carry large amounts of current it produces large torque.

TM RATING

VOLTAGE	: 750 V
CAPACITY	:630 KW
CURRENT	:900A
SPEED	:895 RPM
POLES	:6

All traction motors are connected in parallel. For electric braking, motors are disconnected from silicon rectifier and the armatures are connected to the braking resistances. The motor enters generating action thus reducing the kinetic energy. The final braking effort is by brake shoes. This type of braking is called dynamic braking. This reduces the braking effort and increases the efficiency of braking thereby reduces the wear and tear of the brake shoes.

4.1 TRACTION MOTOR CURRENTS

The current flowing through the traction motor throughout the course ofits use is not constant. It can vary from time to time. The motor has the tendency to consume current that is above the maximum or below the minimum rating. If it consume say an increase in 10% of normal current continuously it is enough to cause flashover or burnouts. The most likely problem that will occur with the series motor is that it will develop an open in one of its windings or between the brushes and the commutator. Since the coils in a series motor are connected in series, each coil must be functioning properly or the motor will not draw any current. When this occurs, the motor cannot build a magnetic field and the armature will not turn. Another problem that is likely to occur with the motor circuit is that circuit voltage will be lost due to a blown fuse or circuit breaker [5]. The motor will respond similarly in both of these conditions. It is possible that the motor will develop a problem but still run. This type of problem usually involves the motor overheating or not being able to pull its rated load. This type of problem is different from an open circuit because the motor is drawing current and trying to run. Since the motor is drawing current, you must assume that there is no open circuit. It is still possible to have brush problems that would require the brushes to be re-seated or replaced. Other conditions that will cause the motor to overheat include loose or damaged field and armature coils. The motor will also overheat if the armature shaft bearing is in need of lubrication or is damaged. The bearing will seize on the shaft and cause the motor to build up friction and overheat. If either of these conditions occurs, the motor should be fixed for extensive repairs. When the motor is restarted after repairs have been made, it is important to monitor the current usage and heat buildup.

V. WHEEL SLIP

When the train is in an uphill or downhill motion there is tendency for the wheels to slip with respect to the track. The speed of the motor increases and the motor consumes abnormal power without doing any work. Although the effect is undesirable it is a perfectly natural phenomenon that cannot be avoided. The wheel slip depends on the geographical terrain, the alignment of wheel with track, the climatic conditions and various others. Many effective measures have been employed presently to avoid this effect [6].

Wheel slip on locos such as the WAP-4/WAG-7, is detected by a relay designated 'QD' which is a current differential relay. It detects the difference in the current flow between two traction motors. If all the traction motors are running at uniform and equal speeds, the armature of the relay remains balanced. However, if any of the axles are slipping, the current to this motor is slightly reduced producing a current imbalance in relay QD which is then triggered. QD gives a repeat to a relay 'Q48' which in turn may activate some automatic wheel-slip reduction procedures. Operation of relay Q48 also lights the LSP (Signal lamp to indicate Wheel-Slip) on the driver's desk.WAG-7 and WAP- 4 have been provided with mainly three methods to minimise wheel slip:

5.1 Sanders to improve adhesion: Sander contains sand that gets sprayed in between the wheel and track in case of wheel slip to increase adhesion. Hence the friction increases and the slipping reduces. Sanders can be operated automatically by relay Q48 or manually.

5.2 Auto-Regression of the Tap-Changer to reduce tractive effort: Q-48 also gives an impulse to relay Q-51 (Relay for Auto-Regression of Tap-Changer) to reduce the notches which in turn lowers the voltage to the traction motors thereby reducing the tractive effort.

5.3 Field Weakening (Weak Field Operation): The DC series motors have their fields wound in series with the armature winding. Normally, the current through the field and the armature is equal but if the current through the field is partially bypassed, the torque of the motor is reduced. Hence, by shunting the field, the tractive effort of the motor is reduced. During wheel slipping, weak field is usually introduced on the leading axles of both the bogies because these are usually the ones to slip first due to dynamic weight transfer which tend to reduce the weight on the leading axles and proportionately increases weight on the trailing axles.

VI. PROBLEMS OF THE PRESENT SYSTEM

The traction motors consumes a reasonable amount of the total cost that is used to build up a locomotive hence its frequent failures and maintenance is not really appreciated. The lesser the failure the more efficient it is and the lesser the maintenance required. Probability for a faulty traction motor in the locos received for maintenance in the loco shed is comparatively high. The problem is that currently there are no such systems that can prevent a motor from behaving abnormally. Continuous consumption of a small increase in current is enough to overheat and cause failure of the motor.

Presently there is no reasonable ways for the loco pilot to understand the current consumption behavior of a motor and avoid the flashing and other problems related to these motors.

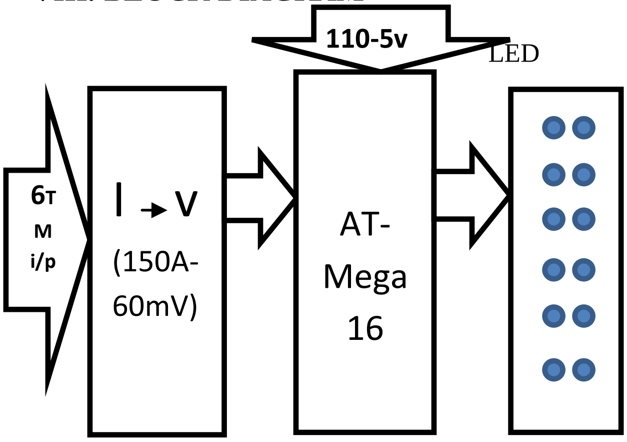
QD used to detect wheel slip is efficient method for avoiding it but in a bogie QD is present only for 1 set of motor the third remains free similar is the case of other bogie. In total the QD is present only for 4 out of 6 motors[7]. The slipping in other two motors cannot be understood by the loco pilot. If at all continuous slipping is reported even after primary protection schemes it is avoided by reducing the current to a whole bogie that is 3 motors hence overall speed reduces and affects the efficiency of the engine.

What we need is a system for the loco pilot to actually isolate the motor that is carrying unusual currents and protect the traction motor before the event of its failures or faults like flashover, pitting, contactor burning etc. The present isolation scheme is based on the assumptions made by the loco pilot.

VII. PROBLEM SOLUTION

The main objective of any shed would be to make the machine as long lasting as possible with minimum amount of maintenance and good efficiency. The solution to this problem would be the development of a system that would help the loco pilot to find out which motor is actually consuming the unusual current and isolate it so that the other motors work and produce the necessary effort to pull the freight. This would help a lot to increase the efficiency of the engine.The present system is an electromechanical system. A digital system can do all the above functions.

VIII. BLOCK DIAGRAM



The 6 traction motor inputs are fed to a microcontroller. The TM currents have a max limit of 1500A and it needs to be converted. Suitable converters are used to convert the current to microvolt level like Hall Effect converter or trans-impedance converter.

The control voltage 110v from the desk is stepped down using a SMPS circuit to 5v and fed to the microcontroller for its working. The output is displayed by a series of LED's. There are 12 LED's in total 6 indicating high current consumption and the other 6 indicting low current consumption. The high or low parameter is set on the basis of the difference current in the QD. That is the maximum limit is 200A in the difference relay. The current difference should not be below or above 200A.

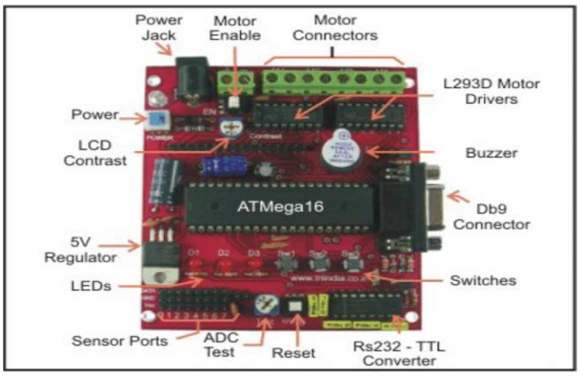
IX. TECHNOLOGICAL BACKGROUNDS

The design and construction of the current detection system has several features that requires specifications for each subsystem. By breaking the design into subsystems a better understanding of the requirements needed to fulfill the objectives is gained.

X. MICROCONTROLLER

The use of the Microcontroller reduces the complexity of the circuitry and controls all the functions needed for the system. Hence a microcontroller that exhibits small size, cheap, external interrupts, UART, small flash memory, processing speed is needed. ATMega16 microcontroller is selected that meets all the required needs for the system. The flash memory is to store the log data through the run time. The AVR i-Board designed is perfect for the system. The features included in i-Board are:

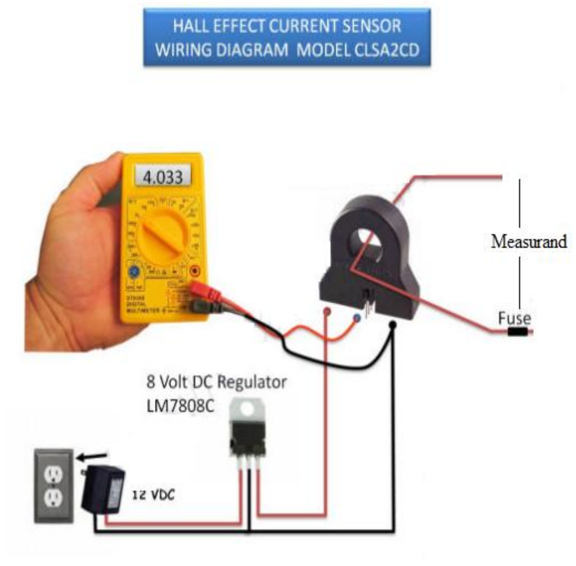
- ATMEL AT-Mega 16 with16kb flash memory
- In system programmable
- On board programmer
- On board regulated power supply
- Power indicator LED
- 3 ON/OFF switch for external interrupts
- On board LCD connector



XI. HALL EFFECT TRANSDUCER

A Hall Effect sensor is a transducer that varies its output voltage in response to a magnetic field. In its simplest form, the sensor operates as an analogue transducer, directly returning a voltage. Electricity carried through a conductor will produce a magnetic field that varies with current, and a Hall sensor can be used to measure the current without interrupting the circuit. Typically, the sensor is integrated with a wound core or permanent magnet that surrounds the conductor to be measured.

The present system employs current shunt resistors to convert the high traction motor output current to measurable values. The main advantage of hall sensors compared to these are that unlike the current shunt sense resistor which can have thermal and temperature heat dissipation issues, it does not become hot.An example connection of a hall sensor is shown below. The diagram shows a 12 Volt DC wall adapter supplying voltage to a 8 Volt regulator. The 7808 Volt regulator puts out a very stable DC voltage.



This is very important because the sensor output is only ~0.032 Volts per Amp that it measures, so if the voltage you are supplying the sensor is noisy, your data will get lost in the noise. The ground is shared throughout the circuit. The sensor used for our system is closed loop precise hall current sensor CYHCS-SH.

The main features are

- Linear output
- AC or DC current sensing
- Fast response time
- Output voltage isolation from input
- Minimum energy dissipation
- Maximum current limited only by conductor size
- Adjustable performance and built-in temperature compensation assures reliable operation
- Accurate, low cost sensing
- Operating temperature range -25 °C to 85 °C

The cost of a Hall Effect sensor is around Rs: 1550. The datasheets is as follows:

Parameters	Specifications
Input Voltage	110VDC Nominal (90-150VDC)
EMI Compliance	In built EMI Filter is provided
Hold Up Time	20mSec.
Efficiency	> 70 - 85%
Line Regulation	0.5%
Load Regulation	0.5%
Ripple	1%Pk-Pk
Protection	Over Voltage, Over Load, Over Temperature & Short Circuit
Operating Temperature	0 - 50 ° C at full rated O/P Power
Storage Temperature	-40 to +85° C
Humidity	0 - 95 % (Non-Condensing)
Cooling	Natural Convectional
Construction	Enclosed DIN (35 X 15) CUM PANEL MOUNTING BKT (2 nos)
Dimensions	165 (W) X 113 (H) X 70 (D) mm 205 (W) X 113 (H) X 78 (D) mm (with mounting bracket).

XII. SMPS (110V TO 12V)

A 80 W Single O/P DC-DC converter 110VDC I/P manufactured by the STARVOX Electronics Limited can be used for conversion of the 110V control voltage available at the drivers panel to 12v DC. This 12v is stepped down to 5v using a 7805 IC. This 5v DC is given as the VCC to the AT-Mega Microcontroller.

XIII. PERFORMANCE EVALUATION

The above described system can pose the solution for the whole problems described above. We have already seen the subsection earlier the traction motor currents reach the microcontroller where the intelligent computations are done. An iterative continuous process is carried out by the microcontroller. Firstly the mean of whole input currents are found out. This value is stored in the temporary register and then the currents are averagedseparately. These separate mean currents are compared to that of the total mean calculated first. If the difference exceeds a tolerance level of 200A the corresponding LED output glows (high or low). After that the current responsible for glowing the LED is omitted and rest of the currents are compared. The comparison is made for both high and low conditions that are high current consumption and low current consumption. This finishes one cycle after this these conditions are repeated. Sometimes due to transient fault the current may rise but it reduces to normal level. So it should be checked and only if the condition is persisting after repeated cycles then the motor needs to be isolated. Once isolated the loco pilot cannot reinstall it until it is checked thoroughly by the shed technicians. The technicians can get a complete log of the run time problems through the serial communication port (RS232) in the i-Board of the microcontroller. Hence in this way the motor carrying abnormal current is notified to the loco pilot in a simple manner and he can protect it before it gets flashed or burned. The system described above can be easily manufactured and installed but the governing factor is the cost. The system costs a reasonable amount but less compared to the amount that it is saving by protecting the traction motors. Hence in every manner we can say that it is an excellent system that needs to be installed into the locos.

The main **advantages** of the system are:

- Compact
- Since microcontroller used it is flexible. It can be modified based on requirements
- Since the Hall Effect sensors are used to measure the high currents, there is no actual contact to these high currents hence proper isolation can be achieved.
- The hall-effect sensor does not get heated up as the current shunt resistor employed now.
- The microcontroller is cheap and has flash memory that helps in data logging.
- The whole system has a comparatively good efficiency and performance

The main **disadvantages** are:

- The cost of hall effect sensor and the SMPS is comparatively high
- A small deviation in the output of the SMPS makes the controller inactive
- Troubleshooting the controller is a troublesome process.

XIV. FUTURE POSSIBILITIES

- The RS-232 communication port of AT-Mega Microcontroller can be used for further communication purposes. It can be modified to transmit the run time details as such to nearest stations.
- Feedback circuits can be incorporated to make the circuit automatic. As microcontrollers are used it can carry out multiple tasks at the same time. Hence many automatic feedback circuits can be installed.
- Many automatic correction circuits employed are electromagnetic relays it can

be replaced using this microcontroller thus reducing the size and improve efficiency as the system becomes intelligent.

- The whole loco operation can be controlled using advanced microcontrollers i.e. automatic pilot systems can be installed in the locos also.
- The MEMU systems used now can be further simplified and the system becomes more rugged.
- Every systems, not only the current system discussed in the project can be monitored and the efficiency of the operation of locomotive increases at an alarming rate.

XV. CONCLUSION

This digitalized current detection scheme is a very helpful system both from the point of view of the Loco pilot and the technicians at the maintenance shed. With the installation of such a device into the locomotives the chances of errors can be reduced by a great percentage. The main objective of any shed would be to make the machine as long lasting as possible with minimum amount of maintenance and this can be achieved if suitable systems are present in the locomotive that overcomes any change from the normal behavior.

This system would help in long lasting of the traction motors used and helps in increasing the efficiency of the locomotive. This current detection scheme helps the loco pilot to isolate the faulty ones and proceed with maximum efficiency with rest of the traction motors.

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